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Comment or Suggested Edit

The greening effect can't be due to increase in CO₂ alone. The fertilization effect needs Nitrogen and phosphorous. There is observational[1] evidence that nitrogen available to plants is decreasing with increasing CO₂ and thus acting to limit fertilization effect. Secondly, the greening of some portions of the planet are likely due to changes in precipitation patterns associated with changing climatic conditions and not entirely attributable to fertilization effect. We will also need to consider that the temperature effect on photosynthesis will also be a limiting mechanism to any continued greening due to fertilization in the future [2]. I recommend acknowledging that the greening is not attributable to CO₂ alone and continued greening in the future with increasing CO₂ is uncertain.

I am glad we acknowledge that CO₂ causes warming, though I am not sure why we are not considering other energy sector related emissions that also cause warming (CFCs/HFCs, methane, aerosol effects). It is not clear what is meant by "CO₂ emissions have tended to overestimate observed trends". This is not correct, the cumulative emissions track the RCP8.5 scenario the closest [3,4]. While there was a decrease in emissions during the Covid-19 period the emissions are now back on track following RCP8.5. This statement should clarify what is meant by the statement in the text.

This paragraph seems to be talking about equilibrium climate sensitivity. The most recent model inter-comparison gives a wider range of climate sensitivities in the range of 1.8 to 5.7 and is wider than estimates of climate sensitivities that have been estimated from paleoclimatic and more recent historical datasets, in the range could be in the range of 2.3 to 4.5 K[5]. The higher sensitivity in the most recent model assessments are an area of active investigation by modelers, the feasibility of a higher range needs to be confirmed with additional observational and process scale modeling [6]. The range for climate sensitivities, 1.8-2.7, should be corrected to the most recent findings, 2.3-4.5. We should also recognize that the (a)earth is a complex system of systems (b)we can't do an experiment to find out what is correct or reduced the uncertainty. As we get better at extracting temperature records and CO₂ concentrations from paleo data, there will be better reconstructions and possibly narrower range along with improvements in modeling that resolve many physical, biological and chemical processes as we get to higher and cloud resolving spatial resolutions.

This is again not true for the majority of the models in the AR6. Figure 7.19 in the IPCC AR6 report shows that majority of the models exhibit a range within the observational range. The models running hot in the most recent decades are the ones with climate sensitivities greater than 5K, which are 3 out of a total of 40 and it should be noted that about the same number of models also are running cold' compared to observed[7]

There is very little dispute that these are challenging issues for climate science. Many of the issues identified here related to compound effects (subsidence and sea-level rise; wildfire and forest management) that requires further scientific investigation. Identifying further research avenues/focus areas will be helpful to firm up some of the challenges faced in using the climate projections as discussed in the paragraph 9.

The focus on uncertainty is relevant and should be emphasized in future research. However, as a reasonable policy pathways, making decisions in the face of these uncertainties is critical. Most of the climate uncertainties that we have confidence at this time can be considered Level 2 and Level 3 uncertainties, approaches such as scenario analysis (and others) are suggested and followed for making hazard and risk estimates for future conditions. For deep uncertainty hazards (for example tornadoes etc.) that we don't have enough data or capability to model, developing methods for assessing the uncertainty and risk should be a focus of future research.

The reason CO₂ was identified as a pollutant is the health consequences of increased temperature, flooding and other climate impacts and not because of any direct affect on health due to exposure to atmospheric CO₂[8].

The summary should note that CO₂ fertilization effects are limited by the availability of other critical plant nutrients (Nitrogen, Phosphorous). The fertilization effect is also constrained by higher temperature effecting photosynthesis[9]

The attribution of greening to primarily CO₂ fertilization is questionable as per recent research. Specifically, in the Northern high latitudes (where the greening is most prominent), increases in temperatures due to climate change has been shown to provide the best explanation[10]. In the sub-Saharan region reforestation efforts and changing precipitation patterns lead to some of the observed greening (the great green wall) [11]. The attribution to CO₂ fertilization should be qualified by noting the other present and emerging constraints.

This summarization ignores the compound effects of temperature, moisture and CO₂ fertilization in assessing the impacts of CO₂ increase on vegetation and crop yields. Many studies have shown that [12]. Making note of these compensating factors is required for a balanced view on CO₂ fertilization effects on plants.

Chen et al. (2024)[13] conclude that "In the attribution analysis of LAI trend and growth rate trend, there were some differences between multiple linear regression model and partial correlation analysis at high latitudes in the northern hemisphere. Partial correlation analysis showed that LAI trend and growth rate trend in this region were mainly affected by temperature and radiation, while multiple linear regression suggested that CO₂ was the dominant driver. The results of the partial correlation analysis seem more reasonable because some previous studies have shown that vegetation change in the high latitudes of the northern Hemisphere is mainly positively affected by climate warming. Multiple linear regression model performed relatively poorly in this region and might not fully identify the contribution of individual drivers. In addition, our model does not include the contribution of land management, which has been highlighted in some previous studies. Of course, the contribution of land management to LAI trend and growth rate trend may be implied in other drivers, such as the positive contribution of CO₂ to LAI trend in PP and PN areas".

This again suffers from not acknowledging the effects of compound and often compensating phenomena that is occurring with the on-going climate change. For example [14] note that much of the Midwest any benefit from CO₂ fertilization will be negated by temperature increases. [15] note that "Our results show that long-term physiological acclimation dampens the initial stimulation of plant net carbon assimilation to elevated [CO₂], and of plant water use to warming."

The fallacy of these arguments in terms of PH changes and evolution is that the changes described in this paragraph occurred over millennia and the evolutionary process had time to adapt; here with climate change we are talking about changes in our lifetime, the speed of change is the issue. This will lead to collapse of some ecosystem and by the time adaptation takes place it will be millions of years and in a different climate - not the one we have now and that enabled the rise of humans.

A simple calculation will show us how misleading this figure is. It shows that over 600 Million years CO₂ changed by around 6000ppm. That is a rate of change of 0.00001/yr; CO₂ changed from 275 to 430 in the past 175 years, that is rate of change of 0.88ppm/yr. A change in the rate of over 10⁵ in magnitude - there in lies the problem. We are seeing a rapid increase in CO₂ that has never been witnessed and the ecosystem and human society (which is at best 10K years old), may not be able to adapt to this rapid change.

The misuse of RCP8.5 as business as usual is acknowledged. However, this was never intended to be a no-policy or business as usual scenario but as a high-end baseline scenario. When dealing with interaction of physical systems with socio-economic projections (which tend to be highly uncertain and policy dependent), the development of this high baseline scenarios is intended to explore the uncertainty ranges that represent a high-end scenario[16,17]. As any engineer would acknowledge, this is a prudent approach when dealing with L3 and L4 type deep uncertainties and provide valid envelopes for assessing uncertainties and risks from high impact events/hazards. The rest of the statements here are uncertainties acknowledged by the climate scientists and included in developing projections and discussing the results[4]. Does the IPCC downplay the role of sun in climate change? The IPCC includes sun variability in all its assessments from the beginning and has been acknowledged as a potential but insignificant contributor.

Please see above. The business-as-usual may be a misnomer but this is an 95% case that is typically included in any type of prudent uncertainty analysis, in particular given the difficulty of predicting the evolution of socio-economic and political conditions over the next 100 years. It should be noted the difference between RCP8.5 and RCP4.5 for mid-century conditions that is of particular focus for adaptation studies is not significant and most of the divergence in these two scenarios occurs later in the century. That the dynamic vegetation models need more development is acknowledged and is a defining challenge for Earth System Modeling for the next decade.

As noted, Parker[18,19,20] has investigated the Urban effects on temperature records. The finding establish that by comparing warm and wind conditions world wide that the impact is negligible. However, as noted by authors, this literature hasn't progressed much over the last decade and much more attention needs to be paid to this question by employing newer models, datasets and analytical techniques available to us at present.

We can all agree that there is a desperate need for developing higher-resolution climate models that can get to cloud resolving scale so that we can represent the cloud feedbacks correctly in the model and avoid uncertainties from parameterization and scale dependency of the parameters. This doesn't make these models useless. The models provide directions for further improvements and necessary changes to reduce the uncertainty bands over the ECS.

The databased approaches have mostly been robust with changes at the high end around 3-4C and at the low end around 1.8 to 2.5C as noted in the chapter. It will be challenging to make this range shorter given the data requirements and uncertainties in data over paleo/haloacene periods. It seems reasonable to estimate that we may have ECS in the range of 3 to 4K (higher than 3.5K being less likely [21]) at the higher end and this should not prevent us from planning and thinking on ways to prevent this possible scenario as it could have major consequences for humans across the planet.

The models range over a factor of three in ECS comparing the most sensitive to the least sensitive models. However vast majority of the models are in 3 to 3.5K sensitivity range and it is probably not correct to assign all models the same amount of importance, given the fact that some of institutes participating in the exercise have different levels of capacity to develop and test models.

While this analysis for the CMIP6 model set is accurate and focuses on a dataset that has shown higher ECS than previous iterations. it should be noted the models have exhibited considerable skill in predicting the subsequent GMST warming[22]. The criticism of the CMIP6 based high ECS models may be premature and probably will have to wait additional time before passing judgement. As noted in [22] these models have shown considerable skill when evaluated on their projections over the past 30-40 years after the projections were published.

A recent study attributes the bias to inter-annual availability and residual bias in the satellite record. The pre- and post 2000 have temperature records from two separate satellites and the discrepancy in the trends needs to be resolved[23]

This is challenge we need to face and work on improving the parametrizations. The new era of super high resolution models would resolve the complex interactions of turbulence, transport and clouds and will provide less uncertainty[24]. However, this can't be used to invalidate the entire set of models, the models are performing remarkably well given the complex system that is being modeled. It should be noted the models do cover the range of the observations and it is not outside the envelope of model predictions.

Part of the problem here may be which part of the stratosphere is sampled and the importance of interannual variabilities in the lower part of the stratosphere. [25] have shown that including the stratosphere as defined from 25 to 50km there is high confidence that the cooling signal caused by CO2 increase is detectable and beyond the noise levels of the natural and inter annual variability in the lowest part of the stratosphere. We should put this debate to rest.

Given the large uncertainties in obtaining data over much of the Northern Hemisphere, using a smaller regional analysis to discount the models may be inappropriate. We should that this remains a question we need to resolve developing better datasets with more seasonal and sub-seasonal coverage to test the model on a global scale

This statement from [26] refers to the fitness of global scale models to resolve regional scale features and argues for developing model at higher spatial resolutions. Using downscaling and other techniques additional insights can be gained at regional scales and provide information for a set of 'purposes'. However, we should work on getting to regional and local scales with GCM as quickly as possible.

Looking for trends or estimating trends in extreme events in current and future climate is not necessarily an attribution study. Estimating frequency, duration and intensity of events helps understand the changing range of the hazard (if there is one). An attribution would be to find to what extent a particular event is influenced or affected by increase in CO2. I would consider these two not to be the same. Attributing any single event to changing climate is perilous, agreed.

As noted by [26] there is not yet any strong evidence that LPT is a fact

I am not sure how one can conclude that the temperature extremes have decreased based on figure 6.3.4. If I understand correctly the Tmax-Tmin for each year was tabulated and a mean of this difference averaged over the 100+ years was subtracted from these values to get some thing like a anomaly. This anomaly seems to have moved from +3F to -3F over the course of q00 years and now trending upwards again. This suggests to me that there has been significant changes in the extremes over the years and the most recent trend is towards warmer highs?

The NCA5 is suggesting that the western US is experiencing increase in extreme heat (page 57, para 4); it seems like figure 6.3.5 establishes the fact and not contradict. There was no claim of pervasive (all CONUS) increase in the report

The definition of heat wave as consecutive 6 days seems to be a special case. The standard definition is exceedance of 85 or 90 percentile for 2 or more days. I can't check with NCA5 as it was taken down from the web

Figure 6.3.6 establishes that heatwaves as defined here have increased in the west and have shown increasing trend all over CONUS in the past 50 years. [27] shows the results for the last 60 years and there is little doubt that there is an increase over most of the CONUS, again the NCA5 report is off the web; figure 6.3.7 shows the heat waves are monotonically increasing from the 1960. Including the longer data is only interesting in the dust bowl 1930 camouflage the signal somewhat for the Midwest and central plains. The problem of taking averages over large regions (for example entire CONUS) is that it kills the peak signals and smooths out the emergent climate change indicators. Doing continental averages to look for extremes is really not very useful. Secondly, there is no particular reason to assume that the climate change signal (i.e. the number of heat waves) should showing up 100 years ago, as the CO2 in the atmosphere started to be of significance in the last 50 years.

averaged over all stations in the region, none of these trend parameters is statistically significant'. This is again how one would be looking at statistics of extremes in precipitation. As we know, precipitation is highly heterogeneous and location dependent. As observed there are trends even with the approaches chosen by the authors of this study compared to NCA5 and averaging that over and saying there is no trend seems disingenuous.

same argument as above

again the issue here is that we are talking about events that are happening in a short-time and over a small region. Averaging over time and space and develop statistics is probably not appropriate when we are talking about events such as the recent flooding event in Texas. If you average that event over 30 days, it will seem unremarkable.

As noted in NCA5 and shown in the analysis presented in figure 6.4.4 there is a clear trend of increase in extreme precipitation in 12 of the 27 stations analyzed. Again averaging over the entire region is not the best method for picking extreme precipitation events that are local both in time and space.

However, there is evidence that flash droughts, which last weeks have increased over the Northeast and Midwest [28]

More recent analysis indicate forest loss due to wildfire accelerating over the recent past[29]. In particular there has been an increase in extreme fire radiative power with a 2 fold increase from 2003 to 2023 (period of satellite data availability)[30][31]. However, that these fires are not out-of-sample and there is a fire deficit as shown in figure 6.8.2 should be acknowledged. But this doesn't alleviate the concern that wildfire is leading to lot of socio-economic concerns and needs to be addressed[32]

The question of forest management and its role on wildfire frequency and intensity is interesting and deserves further study.

The global mean sea-level was increasing at a rate of 0.08 inches/yr in 1993 compared 0.18 inches/yr in 2023, almost double the rate[33], which is approximately what is needed to meet the NOAA projections by mid-century and seems plausible.

A possible reason the method used by IPCC (optimal fingerprinting) can be considered to address McKitnick criticism is in [34]

The role of clouds remains the single most uncertainty in climate modeling, I am glad this was acknowledged here.

The substance of this paragraph was addressed in my comments in earlier sections. Some of the claims made here are either exaggerations of the usual practice (RCP8.5 being referred to as BAU) or the comment about not fit for purpose (a comment extracted from a publication that is calling out for cloud resolved models.

The problem with both the FACE studies and the soybean, Maize and wheat studies cited here are that they don't consider the effect of increase in temperature, changes in precipitation, humidity and other environmental factors along with CO2 increases. These compound effects have been shown in wide number of studies [35] [36][37][38][39]. A meta analysis of the compound effects shows that increase in CO2, along with temperature, precipitation changes effects the quality of the cereal and yields[40]. Another recent study evaluated the impacts on C3 and C4 crops and conclude that CO2 enrichment for C3 crops could increase but will be compensated by temperature increase. CO2 fertilization effect was found to be small for C4 [41]. It is important therefore that we consider the compound effects on crop yields and not just focus on CO2 enrichment.

Taylor and Schlenker 2021 also note that 'Climate change will likely have negative impact on agriculture in aggregate, especially in regions exposed to extreme heat. And the CO2-driven yield increases may be offset by effects on food nutrition and quality'. However, the results for US have been a net positive in the recent past but not true in the lower latitudes.

The criticism of NOAA Billion dollar map is likely warranted as it was never completely transparent how the data was generated. However, changing the baseline assumption and refactoring the data using a different set of criteria to make the effects smaller also doesn't make sense. We should continue collecting this data and make the data accessible for researchers and peer review. Figure 10.1 doesn't address these issues, it is another methodology with unknown provenance of the data.

Climate change can be expected to increase cold weather extremes in regions that have not been exposed to these effect

The same Nobel prize winning model in its most recent study concludes that [42] "We conclude with three results relevant for climate policy. First, both current policies (base run) and the extended Paris Accord fall short of limiting global warming to 2 °C or to the cost–benefit optimal level. Second, the economic stakes in global climate policy are substantial, with estimated net present value of economic benefits around \$120 trillion from the cost–benefit optimal policy. Third, once differences in discounting are considered, the baseline DICE-2023 estimate of the social cost of carbon (\$66/tCO₂ for 2020) aligns closely with other recent estimates". Obviously this is the latest and the current version of the model and these results are quite different from thus discussed on this page. These conclusions should also be included in this discussion to avoid selective reading of the literature.

Similar empirical studies [43] point to "Using an empirical approach that provides a robust lower bound on the persistence of impacts on economic growth, we find that the world economy is committed to an income reduction of 19% within the next 26 years independent of future emission choices (relative to a baseline without climate impacts, likely range of 11–29% accounting for physical climate and empirical uncertainty). These damages already outweigh the mitigation costs required to limit global warming to 2 °C by sixfold over this near-term time frame and thereafter diverge strongly dependent on emission choices. Committed damages arise predominantly through changes in average temperature, but accounting for further climatic components raises estimates by approximately 50% and leads to stronger regional heterogeneity. Committed losses are projected for all regions except those at very high latitudes, at which reductions in temperature variability bring benefits. The largest losses are committed at lower latitudes in regions with lower cumulative historical emissions and lower present-day income". This study uses more of the daily temperature precipitation from 1600 hundred locations world wide instead of global means. There are numerous studies that show the cost, many described in the COP 21 and follow-on meetings

while small in terms of global emissions (just from the US transport sector), over period this will be significant reduction. We need to remember that US is the second highest emitter of CO₂.

[1] Rachel E. Mason et al. Evidence, causes, and consequences of declining nitrogen availability in terrestrial ecosystems. *Science* 376, eabh3767(2022). DOI:10.1126/science.abh3767 [2]
C.E. Moore, et al. The effect of increasing temperature on crop photosynthesis: from enzymes to ecosystems. *Exp. Bot.*, 72 (8) (2021), pp. 2822-2844

[3] C.R. Schwalm, S. Glendon, & P.B. Duffy, RCP8.5 tracks cumulative CO₂ emissions, *Proc. Natl. Acad. Sci. U.S.A.* 117 (33) 19656-19657, <https://doi.org/10.1073/pnas.2007117117> (2020).

[4] C.R. Schwalm, S. Glendon, & P.B. Duffy, Reply to Hausfather and Peters: RCP8.5 is neither problematic nor misleading, *Proc. Natl. Acad. Sci. U.S.A.* 117 (45) 27793-27794, <https://doi.org/10.1073/pnas.2018008117> (2020).

[5] Sherwood, S. C., Webb, M. J., Annan, J. D., Armour, K. C., Forster, P. M., Hargreaves, J. C., et al. (2020). An assessment of Earth's climate sensitivity using multiple lines of evidence. *Reviews of Geophysics*, 58, e2019RG000678.

<https://doi.org/10.1029/2019RG000678> [6] Zelinka, M. D., Myers, T. A., McCoy, D. T., Po-Chedley, S., Caldwell, P. M., Ceppi, P., et al. (2020). Causes of higher climate sensitivity in CMIP6 models. *Geophysical Research Letters*, 47, e2019GL085782. <https://doi.org/10.1029/2019GL085782>

[7] Hausfather, Z., Drake, H. F., Abbott, T., & Schmidt, G. A. (2020). Evaluating the performance of past climate model projections. *Geophysical Research Letters*, 47, e2019GL085378. <https://doi.org/10.1029/2019GL085378>

[8] <https://www.cdc.gov/climate-health/php/effects/index.html>

[9] Xinyuan Wei et al 2025 Environ. Res. Lett. 20 064013

[10] Liu, J., Wennberg, P.O. An emergent constraint on the thermal sensitivity of photosynthesis and greenness in the high latitude northern forests. *Sci Rep* 14, 6189 (2024). <https://doi.org/10.1038/s41598-024-56362-1> [11]

Francesco S.R. Pausata, Marco Gaetani, Gabriele Missouri, Alexis Berg, Danielle Maia de Souza, Rowan F. Sage, Peter B. deMenocal, The Greening of the Sahara: Past Changes and Future Implications, *One Earth*, Volume 2, Issue 3, 2020, Pages 235-250, ISSN 2590-3322, <https://doi.org/10.1016/j.oneear.2020.03.002>.

[12] Lesk, C., Anderson, W., Rigden, A. et al. Compound heat and moisture extreme impacts on global crop yields under climate change. *Nat Rev Earth Environ* 3, 872–889 (2022). <https://doi.org/10.1038/s43017-022-00368-8>

[13] Xin Chen, Tiexi Chen, Bin He, Shuci Liu, Shengjie Zhou, Tingting Shi, The global greening continues despite increased drought stress since 2000, *Global Ecology and Conservation*, Volume 49, 2024, e02791, ISSN 2351-9894,

[14] Ursula M. Ruiz-Vera, Matthew Siebers, Sharon B. Gray, David W. Drag, David M. Rosenthal, Bruce A. Kimball, Donald R. Ort, Carl J. Bernacchi, Global Warming Can Negate the Expected CO₂ Stimulation in Photosynthesis and Productivity for Soybean Grown in the Midwestern United States, *Plant Physiology*, Volume 162, Issue 1, May 2013, Pages 410–423, <https://doi.org/10.1104/pp.112.211938> [15] Lamba S, Hall M,

Räntfors M, et al. Physiological acclimation dampens initial effects of elevated temperature and atmospheric CO₂ concentration in mature boreal Norway spruce. *Plant Cell Environ.* 2018; 41: 300–313. <https://doi.org/10.1111/pce.13079>

[16]van Vuuren, D.P., Edmonds, J., Kainuma, M. et al. The representative concentration pathways: an overview. *Climatic Change* 109, 5 (2011). <https://doi.org/10.1007/s10584-011-0148-z>

[17]Hausfather, Z. (2025). An assessment of current policy scenarios over the 21st century and the reduced plausibility of high-emissions pathways. *Dialogues on Climate Change*, 2(1), 26-32. <https://doi.org/10.1177/29768659241304854> (Original work published 2025)

[18] Parker, D. Large-scale warming is not urban. *Nature* 432, 290 (2004). <https://doi.org/10.1038/432290a>

[19]Parker, D.E. (2010), Urban heat island effects on estimates of observed climate change. *WIREs Clim Change*, 1: 123-133. <https://doi.org/10.1002/wcc.21>.

[20]Parker, D. E., 2006: A Demonstration That Large-Scale Warming Is Not Urban. *J. Climate*, 19, 2882–2895, <https://doi.org/10.1175/JCLI3730.1>.

[21] Michael Mann, *Our Fragile Moment: How lessons from Earth's past can help us survive climate crisis*, Hachette

[22] Hausfather, Z., Drake, H. F., Abbott, T., & Schmidt, G. A. (2020). Evaluating the performance of past climate model projections. *Geophysical Research Letters*, 47, e2019GL085378. <https://doi.org/10.1029/2019GL085378>

The Chung et al. study (which did not go beyond 2014) confirms the models' too-high warming rates as well as documenting the shift in tropospheric temperatures of the RSS and UW datasets (which share very similar choice of satellites) relative to UAH and NOAA/STAR (which rely on empirical tests to determine when a satellite drifts too much). Christy et al. 2018 specifically examined the relative jump in RSS and UW datasets around 2000 finding that compared with other independent measures, the RSS and UW retain spurious warming from the aging NOAA-14 satellite. Thus the notion that satellite biases are an issue applies predominantly to RSS and UW. We agree that the timing of major events like ENSOs diminishes the fidelity of models to observations comparisons, but now with 46 years of record in Fig. 5.7, this concern is less valid. Be that as it may, CGW Fig. 5.7 is clear in noting all models overestimate the tropical temperature trend - even more positive than that of RSS and the two Reanalyses. [23] Chung, ES., Kim, SJ., Sohn, BJ. et al. Multi-decadal climate variability and satellite biases have amplified model-observation discrepancies in tropical troposphere warming estimates. *Commun Earth Environ* 5, 342 (2024). <https://doi.org/10.1038/s43247-024-01510-8>

[24] Merlis, T. M., Guendelman, I., Cheng, K.-Y., Harris, L., Chen, Y.-T., Bretherton, C. S., et al. (2024). The vertical structure of tropical temperature change in global storm-resolving model simulations of climate change. *Geophysical Research Letters*, 51, e2024GL111549. <https://doi.org/10.1029/2024GL111549>

[25] B.D. Santer, S. Po-Chedley, L. Zhao, C. Zou, Q. Fu, S. Solomon, D.W.J. Thompson, C. Mears, & K.E. Taylor, Exceptional stratospheric contribution to human fingerprints on atmospheric temperature, Proc. Natl. Acad. Sci. U.S.A. 120 (20) e2300758120, <https://doi.org/10.1073/pnas.2300758120> (2023).

[26] Cohn, T. A., and H. F. Lins (2005), Nature's style: Naturally trendy, Geophysics. Res. Lett., 32, L23402, doi:10.1029/2005GL024476.

For each station and each year, the hottest day and coldest night are determined and their difference cc

As correctly suggested by Reviewer 1, there are numerous ways to define a heat wave. CWG chose to

As discussed in the CWG text, the EPA chart is (1) based on nighttime temperatures in the 50 largest l

Extreme event totals are 1-day to 5-days depending on section discussed.

The paper referenced by Reviewer 1 begins with data so recent (1999) that it cannot provide evidence for long-term changes in drought even though it suggests an increase in "flash droughts" over that period. Keep in mind, the DM is a product of subjective interpretation and objective measures - objective measures that have changed considerably during the past 25 years. (One of the CWG authors was an official contributor to the DM for 15 years.) One would wonder what would the 1920's, 30's and early 50's reveal if the DM was operational back then? A more consistent metric is provided in CWG Fig. 6.7.1.

[28] Ronald D. Leeper, Rocky Bilotta, Bryan Petersen, Crystal J. Stiles, Richard Heim, Brian Fuchs, Olivier P. Prat, Michael Palecki, Steve Ansari

[29] Tyukavina Alexandra, Potapov Peter, Hansen Matthew C., Pickens Amy H., Stehman Stephen V., Turubanova Svetlana, Parker Diana, Zalles Viviana, Lima André, Kommareddy Indrani, Song Xiao-Peng, Wang Lei, Harris Nancy; Global Trends of Forest Loss Due to Fire From 2001 to 2019, *Frontiers in Remote Sensing*. Volume 3 – 2022, 2022.

[30] Cunningham, C.X., Williamson, G.J. & Bowman, D.M.J.S. Increasing frequency and intensity of the most extreme wildfires on Earth. *Nat Ecol Evol* 8, 1420–1425 (2024).

<https://doi.org/10.1038/s41559-024-02452-2>

[31] Patrick H.

Freeborn, W. Matt Jolly, Mark A. Cochrane, Gareth Roberts, Large wildfire driven increases in nighttime fire activity observed across CONUS from 2003–2020, *Remote Sensing of Environment*, Volume 268, 2022, 12777

[32] Parks, S.A., Guiterman, C.H.,

Margolis, E.Q. et al. A fire deficit persists across diverse North American forests despite recent increases in area burned. *Nat Commun* 16, 1493 (2025).

<https://doi.org/10.1038/s41467-025-56333-8>

[33] Hamlington, B.D., Bellas-Manley, A., Willis, J.K. et al. The rate of global sea level rise doubled during the past three decades. *Commun Earth Environ* 5, 601 (2024).

<https://doi.org/10.1038/s43247-024-01761-5>

[34]Chen, H., Chen, S.X. & Mu, M. A statistical review on the optimal fingerprinting approach in climate change studies. *Clim Dyn* 62, 1439–1446 (2024).
<https://doi.org/10.1007/s00382-023-06975-5>

[35] Ruiz-Vera UM, Siebers M, Gray SB, Drag DW, Rosenthal DM, Kimball BA, Ort DR, Bernacchi CJ. Global warming can negate the expected CO₂ stimulation in photosynthesis and productivity for soybean grown in the Midwestern United States. *Plant Physiol.* 2013 May;162(1):410-23

[36] Levine LH, Richards JT, Wheeler RM. Super-elevated CO₂ interferes with stomatal response to ABA and night closure in soybean (*Glycine max*). *J Plant Physiol.* 2009 Jun 1;166(9):903-13.

[37]Večeřová K, Oravec M, Puranik S, Findurová H, Veselá B, Opoku E, Ofori-Amanfo KK, Klem K, Urban O, Sahu PP. Single and interactive effects of variables associated with climate change on wheat metabolome. *Front Plant Sci.* 2022 Oct 10;13:1002561.

[38]Thomas, J.M.G., Boote, K.J., Allen, L.H., Gallo-Meagher, M. and Davis, J.M. (2003), Elevated Temperature and Carbon Dioxide Effects on Soybean Seed Composition and Transcript Abundance. *Crop Sci.*, 43: 1548-1557.

<https://doi.org/10.2135/cropsci2003.1548> [39] Lesk,

C., Anderson, W., Rigden, A. et al. Compound heat and moisture extreme impacts on global crop yields under climate change. *Nat Rev Earth Environ* 3, 872–889 (2022).

<https://doi.org/10.1038/s43017-022-00368-8>

[40] Ben Mariem S, Soba D, Zhou B, Loladze I, Morales F, Aranjuelo I. Climate Change, Crop Yields, and Grain Quality of C3 Cereals: A Meta-Analysis of [CO₂], Temperature, and Drought Effects. *Plants.* 2021; 10(6):1052. <https://doi.org/10.3390/plants10061052>

[41]Rezaei, E.E., Webber, H., Asseng, S. et al. Climate change impacts on crop yields. *Nat Rev Earth Environ* 4, 831–846 (2023). <https://doi.org/10.1038/s43017-023-00491-0>

[42]L. Barrage, & W. Nordhaus, Policies, projections, and the social cost of carbon: Results from the DICE-2023 model, *Proc. Natl. Acad. Sci. U.S.A.* 121 (13) e2312030121, <https://doi.org/10.1073/pnas.2312030121> (2024).

[43] Kotz, M., Levermann, A. & Wenz, L. The economic commitment of climate change. *Nature* 628, 551–557 (2024). <https://doi.org/10.1038/s41586-024-07219-0>



te Group Inc., 2024.

omputed. These differences are then geographcially averaged for the CONUS and then an overall ε

o follow one defimtion discussed in NCA4 (pg 191) and use 6 consecutive days with Tmax > 90th pe

JS cities and (2) begins in 1961 which was the start of the coolest decade in over 100 years, thereby



average is removed to show the results as a type of anomaly. Reviewer 1 is correct, as indicated in

percentile so to allow for consistent comparisons. However, changing the parameters will do little to e

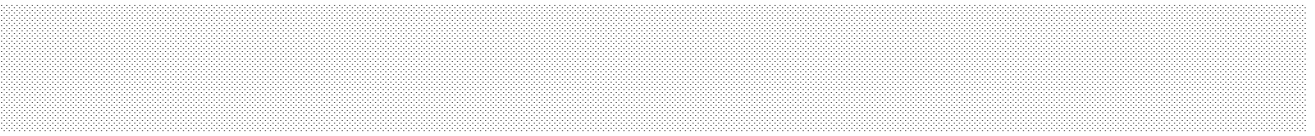
preconditioning the chart to have an upward trend. Urbanization is most clearly seen in nighttime te



the text, Tmin temperatures are almost universally rising more rapidly than Tmax, hence, the difference

alter the fundamental result that the 1920's to early 1950's contain the major heat wave events for the

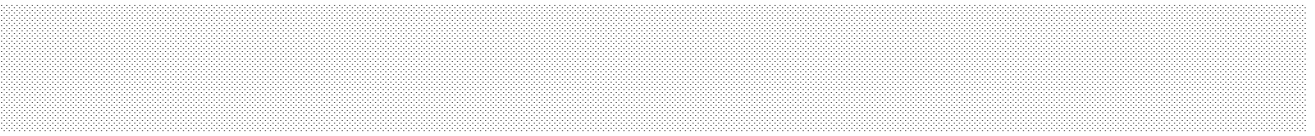
temperature increases so this does not represent a change in the background climate, but more likely



nce (or range) has declined overall. The flattening (or slight rise in the metric) in the past 20 years is

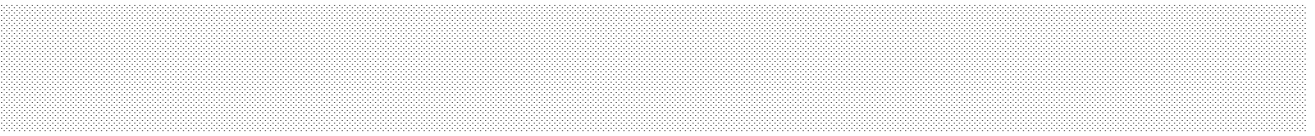
e CONUS.

/ the local climates of cities. Rural areas show less nighttime warming. And avoiding earlier warm p



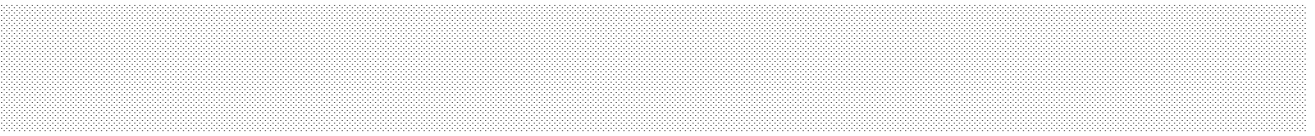
s clearly within the natural range, but does reveal an interesting stair-step pattern with rapid declines

periods does not provide information on the larger scale of natural variability. [27]<https://www.epa.gov>

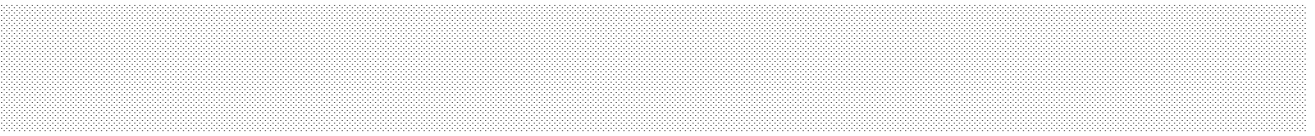


; centered around the 1940's and 1990's and relatively flat periods in between. An explanation is ur

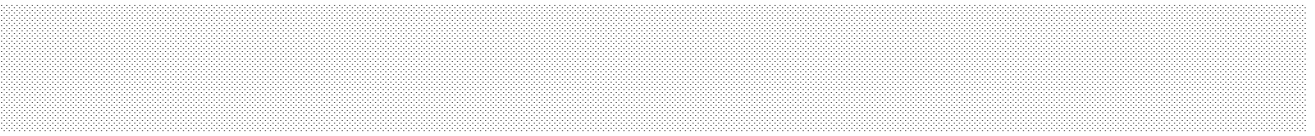
v/climate-indicators/climate-change-indicators-heat-waves



nder investigation, and a leading hypothesis is that there was rapid growth of manufactured surfaces



; around weather stations in the 1940s. Then, in the 1960s-80s many stations were re-located to rel



latively rural airports, which then experienced subsequent growth in manufactured surfaces around



their weather statio